Short- and long-term effects of digital prevention and treatment interventions for cannabis use reduction: A systematic review and meta-analysis

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Abstract: BACKGROUND: Frequent Cannabis use has been linked to a variety of negative mental, physical, and social consequences. We assessed the effects of digital prevention and treatment interventions on Cannabis use reduction in comparison with control conditions. METHODS: Systematic review with two separate meta-analyses. Thirty randomized controlled trials met the inclusion criteria for the review, and 21 were included in the meta-analyses. Primary outcome was self-reported Cannabis use at post-treatment and follow-up. Hedges's g was calculated for all comparisons with non-active control. Risk of bias was examined with the Cochrane risk-of-bias tool. RESULTS: The systematic review included 10 prevention interventions targeting 8138 participants (aged 12 to 20) and 20 treatment interventions targeting 5195 Cannabis users (aged 16 to 40). The meta-analyses showed significantly reduced Cannabis use at post-treatment in the prevention interventions (6 studies, N = 2564, g = 0.33; 95% CI 0.13 to 0.54, p = 0.001) and in the treatment interventions (17 comparisons, N = 3813, g = 0.12; 95% CI 0.02 to 0.22, p = 0.02) as compared with controls. The effects of prevention interventions were maintained at follow-ups of up to 12 months (5 comparisons, N = 2445, g = 0.22; 95% CI 0.12 to 0.33, p < 0.001) but were no longer statistically significant for treatment interventions. CONCLUSIONS: Digital prevention and treatment interventions showed small, significant reduction effects on Cannabis use in diverse target populations at post-treatment compared to controls. For prevention interventions, the post-treatment effects were maintained at follow-up up to 12 months later.

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Review

Short- and long-term effects of digital prevention and treatment interventions for cannabis use reduction: A systematic review and meta-analysis

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ABSTRACT

Background: Frequent Cannabis use has been linked to a variety of negative mental, physical, and social consequences. We assessed the effects of digital prevention and treatment interventions on Cannabis use reduction in comparison with control conditions.

Methods: Systematic review with two separate meta-analyses. Thirty randomized controlled trials met the inclusion criteria for the review, and 21 were included in the meta-analyses. Primary outcome was self-reported Cannabis use at post-treatment and follow-up. Hedges's g was calculated for all comparisons with non-active control. Risk of bias was examined with the Cochrane risk-of-bias tool.

Results: The systematic review included 10 prevention interventions targeting 8138 participants (aged 12 to 20) and 20 treatment interventions targeting 5195 Cannabis users (aged 16 to 40). The meta-analyses showed significantly reduced Cannabis use at post-treatment in the prevention interventions (6 studies, $N = 2564$, $g = 0.33$; 95% CI 0.13 to 0.54, $p = 0.001$) and in the treatment interventions (17 comparisons, $N = 3813$, $g = 0.12$; 95% CI 0.02 to 0.22, $p = 0.02$) as compared with controls. The effects of prevention interventions were maintained at follow-ups of up to 12 months (5 comparisons, $N = 2445$, $g = 0.22$; 95% CI 0.12 to 0.33, $p < 0.001$) but were no longer statistically significant for treatment interventions.

Conclusions: Digital prevention and treatment interventions showed small, significant reduction effects on Cannabis use in diverse target populations at post-treatment compared to controls. For prevention interventions, the post-treatment effects were maintained at follow-up up to 12 months later.

1. Introduction

Cannabis is globally one of the most widely used substances, with average lifetime prevalence rates of 46% among adults in the USA (CBHSQ, 2016), 35% in Australia (AIHW, 2017), and 26% in Europe (EMCDDA, 2018). Although Cannabis is commonly viewed as a harmless drug in Western cultures (Hurd et al., 2014), frequent Cannabis use has been found to be associated with a variety of negative mental, physical, and social consequences (Hall, 2015), such as heightened risk for psychosis (Di Forti et al., 2015), reduced learning ability (Houck et al., 2013), socioeconomic problems (Cerdá et al., 2016), anxiety and panic attacks (Crippa et al., 2009), and reduced

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social functioning (Ansell et al., 2015). The severity of these health and psychosocial problems increase with earlier ages of Cannabis use onset (Gage et al., 2016; Lynskey et al., 2003).

Given the substantial impact that Cannabis use might have, a variety of prevention and treatment options are in place to prevent and treat Cannabis use in various target groups. Prevention interventions mainly target young participants, regardless of their Cannabis use status, since Cannabis initiation most commonly occurs during adolescence (Coffey and Patton, 2016; Pinchevsky et al., 2012). Treatment interventions focus on treatment-seeking Cannabis users. Several meta-analyses have previously shown face-to-face prevention and treatment interventions to be effective in reducing Cannabis use in adolescents and adults (Davis et al., 2015; Gates et al., 2016; Porath-Waller et al., 2010).

However, as the numbers of Cannabis users rise and the demand for prevention and treatment increases (Montanari et al., 2017), new strategies should be evaluated that consider the limited capacities of traditional prevention and treatment facilities. Digital prevention and treatment interventions could be a novel approach to expand accessibility of evidence-based health services. Specifically, by removing barriers such as distance and stigmatization, such interventions can make prevention and treatment available independent of time and place, thus lowering the threshold to access care (Taylor and Luce, 2003) and potentially delivering a strong public health impact.

Unfortunately, few randomized controlled trials (RCTs) have yet been conducted to assess digital prevention and treatment interventions in terms of Cannabis use reduction, as was observed in two prior meta-analyses (Olmos et al., 2018; Tait et al., 2013). The study by Tait and colleagues (Tait et al., 2013) concluded that digital interventions appeared to effectively reduce Cannabis use in adolescents and adults at post-treatment, albeit with a limited number of available RCTs (10 studies by 2012, 5 prevention and 5 treatment interventions). The meta-analysis by Olmos and colleagues (Olmos et al., 2018) came to a similar conclusion after identifying 9 RCTs (search conducted in 2015, 7 intervention and 2 prevention studies).

These previous meta-analyses did not distinguish in their inclusion criteria between prevention and treatment interventions, which – given the substantial differences, most notably in terms of target groups – might have complicated the interpretation of the provided pooled effect estimates of Cannabis use reduction. Additionally, the previous meta-analyses pooled together active and non-active control comparisons, possibly inducing further heterogeneity and leading to ambiguity as to absolute and relative treatment efficacy. The field has matured in subsequent years, and we therefore decided to perform a systematic review and two separate meta-analyses to assess the effectiveness of digital prevention and treatment interventions in reducing Cannabis use at post-treatment and follow-up in comparison to control conditions.

2. Methods

2.1. Identification of studies

A systematic literature search was conducted up to October 10, 2018, identifying 419 potentially eligible studies through the following databases: PubMed, EMBASE, PsycINFO, and the Cochrane Central Register of Controlled Trials (see Appendix A for the full search string we applied for PubMed). An RCT filter was applied. Our selection strategy was based on titles and abstracts. We included interventions that were internet- or computer-based, but for the sake of brevity we will refer to the included interventions as digital interventions. Subsequently, the full texts of studies were retrieved and assessed in terms of inclusion criteria. The search and screening were performed by two of the authors (N.B. and L.L.) independently; in cases of disagreement, consensus was reached by discussion.

2.2. Eligibility criteria

The eligibility criteria varied slightly between our systematic review and the meta-analyses. For the systematic review, we decided to include RCTs of prevention and treatment interventions regardless of their intervention type and control comparisons. Polysubstance use interventions, targeting Cannabis use among other substances, were eligible as long as Cannabis use was reported separately. A measure of Cannabis use at post-treatment – assessed via self-report, toxicology screening or both – had to be included. For the meta-analyses, we excluded prevention and treatment interventions that were compared with active control conditions, since inclusion of differing comparators might have resulted in ambiguous estimations of absolute and relative treatment efficacy (Karlsson and Bergmark, 2015). We also decided to include only self-report outcomes in the meta-analyses, thereby excluding studies that reported toxicology screening outcomes only. Although toxicology screening is a reliable way to measure heavy Cannabis use, it is less reliable for detecting mild use or frequency of use (Taylor et al., 2017).

2.3. Quality assessment

The validity of all RCTs was assessed using the Cochrane risk-of-bias tool (Higgins et al., 2011). Specifically, we assessed (a) adequacy of allocation sequence generation, (b) concealment of the allocation to the particular conditions, (c) blinding of the participants and personnel, (d) blinding of the outcome assessors, (e) appropriate handling of incomplete outcome data by utilizing an intention-to-treat (ITT) design, (f) selective outcome reporting, and (g) other potential threats to validity. Risk of bias was independently evaluated by two of the authors (N.B. and L.L.); in the event of disagreement, consensus was reached by discussion.

2.4. Data extraction

Outcome measures assessing Cannabis use were extracted; these included self-reported frequency of use or scores on self-report questionnaires, as recorded at post-treatment and furthest follow-up (3 to 12 months). We also extracted various characteristics of the studies.

2.5. Meta-analyses

All analyses were carried out with the computer program Comprehensive Meta-Analysis (CMA, version 3.3.070). Effect sizes were calculated by subtracting the mean post-treatment result of the experimental condition from the mean post-treatment result of the control condition and dividing that difference by the pooled standard deviation of the two (Cohen, 1988), or by converting test statistics (*F, r*) into standardized mean differences (Lipsey and Wilson, 2001). Effect sizes of about 0.8 can be considered large, 0.5 moderate, and 0.2 small (Cohen, 1988). For studies with two or more intervention conditions, we separated the control condition into two or more groups, dividing the sample size by that number (Becker et al., 2014; Blow et al., 2017; Schaub et al., 2015). Subsequently, experimental conditions were compared separately with the relevant control conditions. Hedges's *g* was computed to indicate the difference in effect sizes for each comparison (Hedges and Olkin, 1985). As we anticipated heterogeneity among the RCTs, we calculated the mean effect sizes using a random-effects model, which implies that the included studies were drawn from populations of studies that systematically differed from one another (Borenstein et al., 2009). To test the homogeneity of effect sizes, we calculated the I^2 heterogeneity statistic; an estimation of zero percent suggests no heterogeneity, whereas 25%, 50%, and 75% suggest low, moderate, and high heterogeneity. We further calculated 95% confidence intervals around I^2 (Ioannidis et al., 2007), applying the non-central chi-square–based approach within the "heterogi" module for

Stata (Orsini et al., 2006). We assessed publication bias by visually inspecting the funnel plot. To assess whether the bias captured by the funnel plot was significant, we used Egger's linear regression test of the intercept (Egger et al., 1997). Duval and Tweedie's trim-and-fill procedure (Duval and Tweedie, 2000) was used to account for potentially missing studies. The presence of outliers was explored by assessing whether effect sizes and 95% confidence intervals of the studies overlapped with the 95% CI of the pooled effect size; in cases where outliers were observed, we conducted an additional analysis without the outliers. Characteristics which, according to the literature, may induce heterogeneity and affect effect sizes were investigated in subgroup analyses (see Table 4, Appendix B) using a mixed-effects model (Borenstein et al., 2009), whereby studies within subgroups were pooled in a random-effects model and analyses for significant differences between subgroups were conducted with a fixed-effects model. Lastly, we conducted three univariable meta-regression analyses to gauge associations between the effect sizes of the digital prevention and treatment interventions, based on self-reported Cannabis use at post-treatment, and (a) intervention duration, (b) number of sessions, and (c) the risk of bias of the assessed studies.

2.6. Power calculation

We calculated the number of RCTs needed to achieve adequate statistical power to determine relevant post-treatment and follow-up effects (Borenstein et al., 2009). Assuming a small effect size of $g = 0.20$ – based on previously conducted meta-analyses (Olmos et al., 2018; Tait et al., 2013) – with a medium level of between-study variance (τ^2), a statistical power of 0.80, and an alpha of 0.05, we calculated that 10 studies including a mean of 66 participants per condition would be necessary, or 20 studies including 33 participants per condition. To detect an effect size of $g = 0.30$, we would need 10 studies with 30 participants per condition or 20 studies with 15 per condition.

3. Results

3.1. Selection and inclusion of studies

From the 419 abstracts (307 after removal of duplicates), we retrieved 70 full-text papers for possible inclusion in our systematic review; 40 of those were excluded because they did not meet our inclusion criteria. A total of 30 studies met all criteria for the systematic review (10 prevention interventions and 20 treatment interventions) and 21 studies for the meta-analyses (6 prevention and 15 treatment interventions). A flowchart describing the inclusion process for the systematic review and the meta-analyses is shown in Fig. 1.

3.2. Characteristics of included prevention interventions

The prevention interventions we identified for the systematic review ($n = 10$) included a total of 8138 participants ($n = 4635$ in the experimental conditions; $n = 3783$ in the comparison conditions; Table 1). The mean ages of their participants ranged from 12 to 20. Four studies recruited participants from a secondary school, three from the community, one from a university setting, one from a clinical setting (unrelated to substance use), and one study recruited exclusively via a social media website. As expected in universal prevention interventions, the RCTs included participants irrespective of their Cannabis use status. The studies included more female (61.4%) than male participants. Overall study attrition ranged from 1.5% to 55% and thus varied considerably. Parent-involvement programs had the smallest attrition rates, ranging from 1.5% to 5.7%, while Climate Schools courses showed attrition rates ranging from 10.5% to 55%.

The majority of the included interventions ($n = 7$) assessed baseline Cannabis use, but it was measured in various ways. The most common measure ($n = 5$) was frequency of use during the previous 1, 3 or 6 months; the other studies ($n = 2$) reported percentages of participants with lifetime Cannabis use. Six of the studies applied an unguided digital prevention intervention that offered no additional support via face-to-face contact or written communication (Elliott and Carey, 2012; Fang et al., 2010; Schinke et al., 2009a, 2009b; Schwinn et al., 2010a; Walton et al., 2014); four studies provided guidance via teacher-delivered class activity to reinforce the information taught in the online components (Champion et al., 2016; Newton et al., 2018, 2010; Vogl et al., 2014). Four of the studied interventions were targeting a variety of substances including Cannabis, two targeted Cannabis use exclusively via Cannabis-specific prevention interventions, three targeted Cannabis and alcohol, and one study targeted Cannabis and psychostimulants.

Eleven comparisons were made, six of which were with non-active comparison conditions (assessment-only, health information brochure) and four with active conditions (drug prevention-as-usual). The applied interventions varied (see Tables 1 and 3). Four studies evaluated Climate Schools courses in secondary schools (Champion et al., 2016; Newton et al., 2010; Vogl et al., 2014), three studies assessed parent-involvement programs (Fang et al., 2010; Schinke et al., 2009a, 2009b), one study evaluated personalized normative feedback (PNF) (Elliott and Carey, 2012), one study assessed a skills-based prevention program (Schwinn et al., 2010b), and one study tested a brief intervention (BI) based on harm reduction and motivational interviewing (MI) (Walton et al., 2014). All the included RCTs employed self-report measures to assess Cannabis use frequency. The studies were carried out in three different countries: USA ($n = 5$), Australia ($n = 4$), and Canada ($n = 1$). Study characteristics are shown in Table 1.

3.3. Quality assessment of the prevention interventions

The methodological quality of the prevention studies we included in our first meta-analysis ($N = 6$) can be observed in detail in Appendix C. One of the six studies reported adequate sequence generation. None reported adequate allocation concealment. None blinded the participants and personnel. As all studies employed self-reporting scales to measure Cannabis use, we considered this lack of blinding in the outcome assessments to entail a high risk of bias; however, given the context of universal prevention interventions, which target large numbers of users and non-users, self-report measures seemed the most realistic approach for measuring Cannabis use. Incomplete outcome data was handled adequately in three studies. Regarding selective outcome reporting, none of the studies had a publicly available protocol or pre-registration, so they could not be assessed for possible protocol violations. No other potential threats to validity were identified in the included studies. In summary, three studies fulfilled one criterion of the possible seven, two studies fulfilled two criteria, and one study fulfilled three criteria.

3.4. Post-treatment and follow-up effects of prevention interventions on Cannabis use

The prevention interventions that were compared to active comparison conditions (4 studies, $n = 6647$) – and which were therefore not included in the first meta-analysis (see Table 1) – reported no significant differences in Cannabis use between conditions at the follow-up assessments. Specifically, the excluded studies compared the Climate Schools intervention with drug prevention-as-usual. The prevention interventions that were compared to non-active control conditions (6 studies, $N = 2564$) showed a small significant effect ($g = 0.33$; 95% CI 0.13 to 0.54) on Cannabis use at post-treatment. Heterogeneity was high (see Fig. 2 and Table 4). No publication bias was indicated via assessment of the funnel plot and Duval and Tweedie's trim-and-fill procedure. Egger's test did not indicate an asymmetric funnel plot ($p = 0.58$). At follow-up assessments up to 12 months later (5 studies, $n = 2445$), the effect decreased slightly but remained statistically

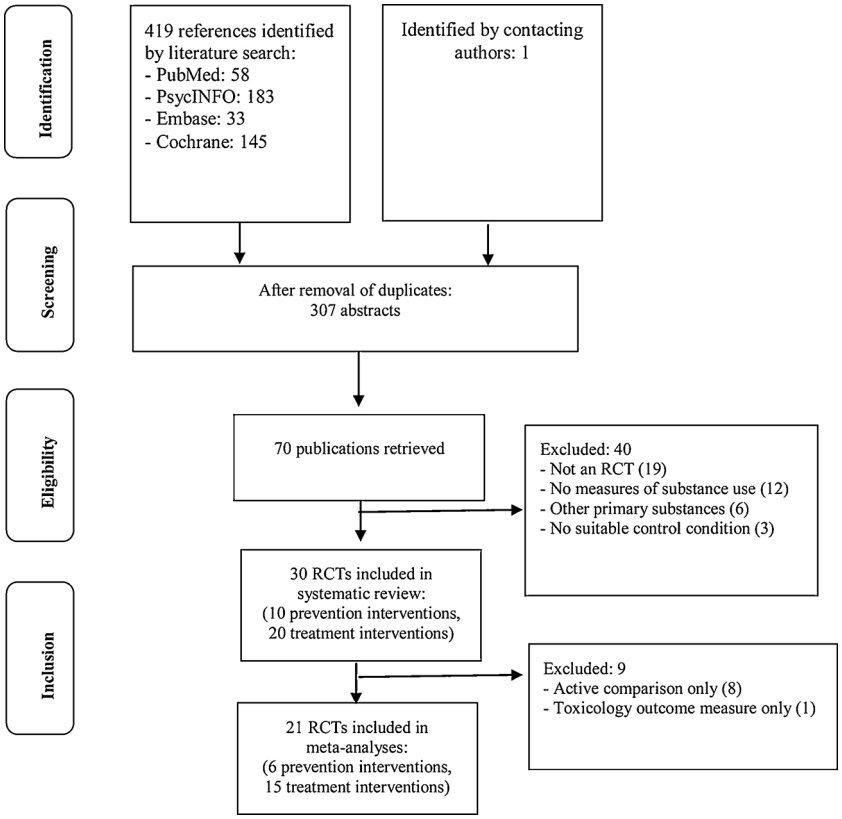

Fig. 1. Flowchart for inclusion of studies in systematic review and meta-analyses.

significant ($g = 0.22$; 95% CI 0.12 to 0.33, $p = 0.001$). Subgroup analyses did not show significant differences between groups (see Table 4). The univariable meta-regression analyses did not reveal significant associations between the effect sizes of the digital interventions and (a) intervention duration in days (slope 0.003; 95% CI − 0.004 to 0.01, $p = 0.421$), (b) number of sessions in the intervention (slope 0.015; 95% CI −0.03 to 0.06, $p = 0.548$), or (c) risk of bias of the studies (slope −0.03; 95% CI −0.34 to 0.28, $p = 0.868$). For the sake of rigor, we additionally report in Appendix E the effect on Cannabis use of the non-included prevention interventions that were compared with active control conditions.

3.5. Characteristics of included treatment interventions

The treatment interventions we identified for the systematic review ($n = 20$) recruited a total of 5195 participants ($n = 3007$ in the experimental conditions; $n = 2188$ in the comparison conditions; Table 2). The mean ages of the participants ranged from 16 to 40; most studies recruited adults aged 18 or older, while one study recruited exclusively adolescents aged 12 to 17. Twelve studies recruited participants with self-reported Cannabis use within varying time frames (e.g. weekly, monthly use). Six studies recruited participants on the basis of various scales: the Alcohol, Smoking and Substance Involvement Screening Test (ASSIST) (WHO Group, 2002), with scores from 4 to 26; the Severity of Dependence Scale (SDS) (Gossop et al., 1995), with scores of ≥ 2 for females and ≥ 4 for males; or the Opiate Treatment Index (OTI) (Darke et al., 1992), with scores of ≥ 0.16. One study recruited participants based on a DSM-IV diagnosis indicating Cannabis abuse or dependence, and a further study recruited participants expressing the wish to participate.

The included studies employed different recruitment strategies. Ten studies recruited from clinical settings, five from university settings, three from the community, and two exclusively online. The studies recruited slightly more male (52%) than female participants. Overall study attrition ranged from 1.4% to 77.2%, thus differing widely. Notably, a brief intervention (BI) and a PNF-based intervention exhibited the smallest attrition rates, ranging from 1.4% to 1.6%, while the solution-focused therapy showed the highest rate at 77.2%. The majority of the included interventions ($n = 17$) assessed baseline Cannabis use, though measured in various ways. The most common measure ($n = 12$) was the number of Cannabis use days in the previous 1 or 3 months; other studies reported the mean ASSIST Cannabis score ($n = 4$) or the percentage of participants using Cannabis at least once during the study period ($n = 1$). The baseline mean number of past-month Cannabis use days was 18.3 ($SD = 10.95$), based on five studies and 1053 individuals; the mean ASSIST Cannabis score was 10.6 ($SD = 6.9$), based on five studies and 1016 individuals.

Twelve RCTs applied an unguided digital intervention, while six provided guidance in the form of therapist sessions or online chat, during which the content of the interventions was discussed and feedback provided. Two studies consisted of a three-arm RCT offering two treatment interventions, with one arm being guided and the other treatment arm unguided. The form of guidance differed, in that one study employed guidance via a chat module (Schaub et al., 2015) and the other provided the intervention with face-to-face therapist guidance (Blow et al., 2017). Eighteen studies applied a stand-alone digital intervention without any additional treatment, while three studies provided an add-on digital intervention adjunctive to face-to-face treatment by a mental health professional.

Eleven of the 20 studies in our systematic review targeted Cannabis as the primary substance of abuse, using Cannabis-specific interventions, whereas nine studies aimed to reduce Cannabis consumption via polysubstance use interventions that also targeted Cannabis. In the 20 studies, 23 comparisons were made, in which 17 interventions were compared with non-active control conditions (education, assessment-only, waitlist) and 6 with active comparison conditions (person-centered therapy, brief intervention [BI], motivational interviewing [MI] plus cognitive-behavioral therapy [CBT], counseling, enhanced usual

Table 1
Selected characteristics of included prevention interventions.

Study	Target group/ Recruitment	Mean age & *SD*	Inclusion criteria	Type of intervention	*N*	Intervention	Comparison	Delivery mode/ Setting	Primary cannabis outcome	*N* of sessions	Duration	Overall attrition	Meta-analysis
Champion et al. (2016)	Secondary school students/ Secondary school	13.3 ± 0.47	No cannabis-specific inclusion criteria	Guided SA alcohol & cannabis prevention	832	Climate Schools course[a]	Drug prevention-as-usual	Internet/ School	SR frequency (past 6 months)	12	NR	20%	No
Elliott and Carey (2012)	University students/ University	20.5 ± 2.7	No past-month use	Unguided SA cannabis prevention	245	PNF	AO	Internet	SR frequency (past month)	1	1D	NR	Yes
Fang et al. (2010)	Asian-Am. girls + mothers/ Community	13.1 ± 0.95	No cannabis-specific inclusion criteria	Unguided SA Substance use prevention	104	Parent-involvement programs	AO	Internet/ Home	SR frequency (past month)	9	9 W	1.9%	Yes
Newton et al. (2010)	High school students/ Secondary school	13.1 ± 0.58	No cannabis-specific inclusion criteria	Guided SA alcohol & cannabis prevention	1296	Climate Schools course[a]	Drug prevention-as-usual	Internet/ School	SR frequency (past 6 months)	12	NR	55%	No
Newton et al. (2018)	High school students/ Secondary school	13.3 ± 0.51	No cannabis-specific inclusion criteria	Guided SA alcohol & cannabis prevention	1712	1 st condition: Climate Schools course[a] 2nd condition: Climate Schools course[a] + group sessions	Drug prevention-as-usual	Internet/ School	SR frequency (past 6 months)	1 st: 12 2nd: 12 + 2 group sessions	NR	27%	No
Schinke et al. (2009a)	Girls/ Community	12.76 ± 1	No cannabis-specific inclusion criteria	Unguided SA Substance use prevention	916	Parent-involvement programs	AO	Internet/ Home	SR frequency (past month)	9 + 2 booster sessions	9 W	5.7%	Yes
Schinke et al. (2009b)	Girls/ Community	12.7 ± 1.1	No cannabis-specific inclusion criteria	Unguided SA Substance use prevention	582	Parent-involvement programs	AO	Internet or CD-ROM/ Home	SR frequency (past month)	9	9 W	1.5%	Yes
Schwinn et al. (2010a,b)	Girls/ Exclusively via social media website	14 ± 0.57	No cannabis-specific inclusion criteria	Unguided SA Substance use prevention	236	Skills-based prevention program	AO	Internet/ Home	SR frequency (past month)	12	6 W	6.8%	Yes
Vogl et al. (2014)	Secondary school students/ Secondary school	15.44 ± 0.41	No cannabis-specific inclusion criteria	Guided SA psychostimulant & cannabis prevention	1734	Climate Schools course[a]	Drug prevention-as-usual	Internet/ School	SR frequency (past 3 months)	6	NR	10.5%	No
Walton et al (2014)	Adolescents in primary care/ Clinical (health center)	14.9 ± 1.9	No prior cannabis use	Unguided SA cannabis prevention	481	BI	Health information brochure	Computer/ Clinical	SR frequency (past 3 months)	1	1D	11.1%	Yes

AO, assessment-only; BI, Brief intervention; D, day; NR, not reported; PNF, personalized normative feedback; SA, stand-alone intervention; SD, standard deviation; SR, self-report; W, week. [a]The Climate Schools courses are an in-school health education program delivered via teachers and online modules.

Table 2
Selected characteristics of included treatment interventions.

Study	Target group/ Recruitment	Mean age & *SD*	Inclusion criteria	Type of intervention and guidance	*N*	Intervention	Comparison	Delivery mode/ Setting	Primary cannabis outcome	*N* of sessions	Duration	Overall attrition	Meta-analysis
Becker et al. (2014)	Cannabis and tobacco users/ Community	29.8 ± 9.5	Cannabis use during past 6 months and tobacco use past 4 weeks	Unguided SA cannabis intervention	325	1 st condition: PNF; 2nd condition: MI	EDUC	Internet	SR frequency (times per week)	1	1D	19.7%	Yes
Blow et al. (2017)	Patients in emergency department/ Clinical	31.2 ± 10.9	ASSIST score ≥ 4	1 st condition: unguided SA polysubstance use intervention 2nd condition: guided SA ditto	779	1 st: BI; 2nd: therapist-delivered BI	Enhanced usual care	Computer/ Clinical	SR frequency (days of use)	1	1D	19.3%	No
Budney et al. (2015)	Treatment-seeking patients/ Clinical	34.9 ± 10.5	At least 50/90 days of use + DMS-IV cannabis abuse or dependence diagnosis	Guided add-on cannabis intervention	75	MI + CBT	1 st condition: therapist-delivered MI + CBT 2nd condition: BI	Internet	SR frequency (days of use) and point prevalence abstinence (urine screening)	9	12 W	31%	No
Christoff et al. (2015)	University students/ University	24 ± 5.4	Cannabis-specific ASSIST score 4–26	Unguided SA polysubstance use intervention [a]	135	MI	AO	Computer/ University	SR ASSIST cannabis scores	1	1D	25%	Yes
Campbell et al. (2014)	Treatment-seeking patients/ Clinical	34.9 ± 10.9	Any illicit drug use prior month	Guided add-on polysubstance use intervention [a]	114	Individual and group counseling + CRA	Individual and group counseling	Internet	Abstinence rates during last 4 weeks of treatment (urine screening)	62	12 W	NR	No
Elliott et al. (2014)	University students/ University	19.3 ± 1.2	Any cannabis use prior month	Unguided SA cannabis intervention	317	PNF	AO	Internet	SR frequency (past month)	1	1D	1.6%	Yes
Gryczynski et al. (2016)	Patients in clinic waiting room/ Clinical	35 ± 13	ASSIST score 4–26	Unguided SA polysubstance use intervention [a]	80	MI	WL	Computer/ Clinical	SR ASSIST cannabis scores + cannabis-positive hair screening	1	1D	8.1%	Yes
Jonas et al. (2012)	Problem cannabis users/ Exclusively via drug-related information website	24.2 ± 5.8	SDS score ≥ 2 or ≥4 (female/ male)	Guided SA cannabis intervention	67	MI	EDUC	Internet	SR frequency (past month)	1	1D	25.8%	Yes
Kay-Lambkin et al. (2009)	Patients with depression + problematic cannabis or alcohol use/ Clinical	35.4[b]	At least weekly use	Guided SA polysubstance use intervention [a]	43	MI + CBT	AO	Computer/ Clinical	SR frequency (past month)	10	10 W	25.6%	Yes
Kay-Lambkin et al. (2011)	Patients with depression + problematic cannabis or alcohol use/ Clinical	40[b]	Cannabis OTI Q score over 0.14	Guided SA polysubstance use intervention [a]	110	MI + CBT	PCT	Computer/ Clinical	SR 50% or more reduction in use frequency	10	10 W	37.3%	No
Lee et al. (2010)	University students/ University	18 ± 0.3	Any use prior 3 months	Unguided SA cannabis intervention	341	PNF	AO	Internet	SR frequency (past 3 months)	1	1D	5%	Yes
Ondersma et al. (2007)	Post-partum women/ Clinical (hospital)	25 ± 5.6	Any use in month prior to pregnancy	Unguided SA polysubstance use intervention [a]	107	MI	AO	Computer/ Clinical	SR frequency (past 4 months) + cannabis-positive urine sample screenings	1	1D	34.6%	Yes
Ondersma et al. (2014)	Post-partum women/ Clinical (hospital)	26.6 ± 6	Any use in month prior to pregnancy	Unguided SA polysubstance use intervention [a]	143	MI	AO	Computer/ Clinical	SR ASSIST cannabis scores	1	1D	26.6%	Yes
Palfai et al. (2014)	University students/ University	19.7 ± 1.3	At least monthly use prior 3 months	Unguided SA cannabis intervention	123	PNF	EDUC	Internet/ Clinical or home	SR frequency (past 3 months)	1	1D	11.8%	Yes

(*continued on next page*)

Table 2 (*continued*)

Study	Target group/ Recruitment	Mean age & *SD*	Inclusion criteria	Type of intervention and guidance	*N*	Intervention	Comparison	Delivery mode/ Setting	Primary cannabis outcome	*N* of sessions	Duration	Overall attrition	Meta-analysis
Rooke et al. (2013)	Cannabis users/ Community	31 ± 9.8	Any use prior month	Unguided SA cannabis intervention	230	MI + CBT	EDUC	Internet	SR frequency (past month)	6	6 W	35.2%	Yes
Schaub et al. (2015)	Cannabis users/ Community	29.8 ± 10	Any use prior month	1 st condition guided SA 2nd condition unguided SA cannabis intervention	308	MI + CBT	WL	Internet	SR frequency (past month)	8	6 W	62%	Yes
Schwartz et al. (2014)	Patients in clinic waiting room/ Clinical (primary care clinics)	36.1 ± 14.6	Between 4-26 on ASSIST	Unguided SA polysubstance use intervention [a]	314	BI	BI	Computer/ Clinical	SR ASSIST cannabis scores + cannabis-positive hair tests	1	1D	1.4%	No
Tossmann et al. (2011)	Cannabis users motivated to reduce use/ Exclusively via drug-related information website	24.7 ± 6.8	Expressed wish to reduce use	Guided SA cannabis intervention	1292	Solution-focused	WL	Internet	SR frequency (past month)	NA	50D	77.2%	Yes
Towe and Stephens (2014)	University students/ University	19.8 ± 1.3	Problematic use at least 6 days in prior month	Unguided SA cannabis intervention	82	PNF	EDUC	Internet	SR frequency (past month)	1	1D	57.3%	Yes
Walton et al. (2013)	Adolescents in clinic waiting room/ Clinical (health center)	16.3 ± 1.6	Past-year cannabis use	Unguided SA cannabis intervention	210	MI	Health information brochure	Computer/ Clinical	SR frequency (past 3 months)	1	1D	14.9%	Yes

AO, assessment-only; ASSIST, Alcohol, Smoking and Substance Involvement Screening Test; BI, brief intervention CBT, cognitive-behavioral therapy; CRA, community reinforcement approach; D, day; EDUC, educational control; MI, motivational interviewing; NR, not reported; PNF, personalized normative feedback; PCT, person-centered therapy; SA, stand-alone intervention; SDS, Severity of Dependence Scale; SD, standard deviation; SR, self-report; TAU, treatment-as-usual; OTI Q, Opiate Treatment Index quotient; W, week; WL, waitlist [a] 'Polysubstance use intervention' denotes an intervention that targets substance use irrespective of the primary substance used. [b] Study did not report standard deviations for the mean age of groups.

Table 3
Definitions of digital interventions for Cannabis users.

Conditions	Definition	N of studies
Motivational interviewing (MI)	A distinct feature of MI is that the patient, rather than the therapist, is the one who voices the arguments for change. MI is based on the person-centered approach of Carl Rogers (Rogers, 1951). In MI, the conditions for growth and change are provided by the therapist, by creating an environment of an egalitarian relationship. MI is distinct from a classic non-directive approach, since therapists in MI direct their clients toward specific outcome goals, using systematic strategies to achieve those goals (Rollnick and Miller, 1995).	8
Personalized normative feedback (PNF)	PNF interventions provide tailored feedback delivered via self-report tools measuring substance use. The feedback regarding individuals' substance use behavior is commonly displayed through bar graphs and compared with the perception they have of substance use norms within their specific reference group and with the actual substance use behavior in that particular group (Dotson et al., 2015).	6
Motivational interviewing (MI) + cognitive-behavioral therapy (CBT)	The combination of MI and CBT is a promising approach in which motivational strategies are applied to initiate motivation for change, while CBT targets dysfunctional thoughts and behaviors that hinder ordinary daily functioning (Naar-King and Safren, 2017).	5
Climate Schools courses	The Climate Schools courses are based on a social influence approach within a harm reduction framework. The interventions are implemented within school curricula. Climate Schools courses provide cartoon-based educational information and are delivered through digital means (Newton et al., 2009).	4
Parent-involvement programs	In the family prevention programs identified here, mother-daughter dyads are recruited with the aims of positively influencing the daughters to adopt healthy, positive behaviors and of preventing risky behaviors such as substance use initiation (Schinke et al., 2009b).	3
Brief interventions (BI)	BIs are concise interventions taking place over a brief period of time. They promote a practical conversation style designed to create a collaborative relationship with the patient. The goal is to work together toward the patient's self-identified aims. BIs are solution-focused and are often associated with MI techniques (Center for Substance Abuse Treatment, 1999).	3
Solution-focused approaches	In solution-focused approaches, the main focus is on finding solutions for the present and on exploring individuals' hopes and goals, thereby identifying potential resolutions to problems (Iveson, 2002).	1
Skills-based prevention programs	Skill-based prevention programs teach adolescents various skills for handling situations that might lead to substance use initiation. Commonly targeted skills include self-efficacy, goal setting, effective communication, dealing with peer pressure, problem solving, and decision making (Schinke et al., 2004).	1
Community reinforcement approach (CRA)	CRA is an extensive behavioral program supporting patients through functional analyses to investigate triggers and consequences of specific behaviors and to develop strategies to either avoid or address those behaviors. CRA makes use of various incentives of a vocational, social, and recreational nature in order to change patients' circumstances (Meyers et al., 2005).	1

care). The applied treatment interventions varied (see Tables 2 and 3). Seven studies applied MI, five applied PNF, five applied combined CBT and MI, two applied BI, and two employed other distinct types of interventions (solution- focused therapy, community reinforcement approach [CRA]). The RCTs were conducted in five countries: USA (n = 12), Australia (n = 3), Germany (n = 2), Switzerland (n = 2), and Brazil (n = 1). Study characteristics are shown in Table 2.

3.6. Quality assessment of the treatment interventions

The methodological quality of the treatment studies we included in our second meta-analysis can be observed in detail in Appendix D. Twelve of the 15 included RCTs reported adequate sequence generation. Seven reported adequate allocation concealment. Two RCTs blinded the participants and personnel by fully automating the randomization procedure online and ensuring that the participants were not aware of the other conditions. As we decided to use the self-report measures to assess Cannabis use, we considered the lack of blinding in the outcome assessments to entail a high risk of bias in all studies – excepting the two cases (Becker et al., 2014; Jonas et al., 2012) in which participants were unaware of other study conditions and the interventions were fully automated, thus ensuring a low risk of detection bias. Eleven studies adequately handled incomplete outcome data through ITT analyses. Regarding selective outcome reporting, a protocol or pre-registration was publicly available in only five cases, so the other studies could not be assessed for possible protocol violations. No other potential threats to validity were identified in the included studies. In summary, two studies fulfilled one of the seven possible criteria, two studies fulfilled two criteria, three studies fulfilled three criteria, four studies fulfilled four criteria, two studies fulfilled five criteria, and one study fulfilled seven criteria.

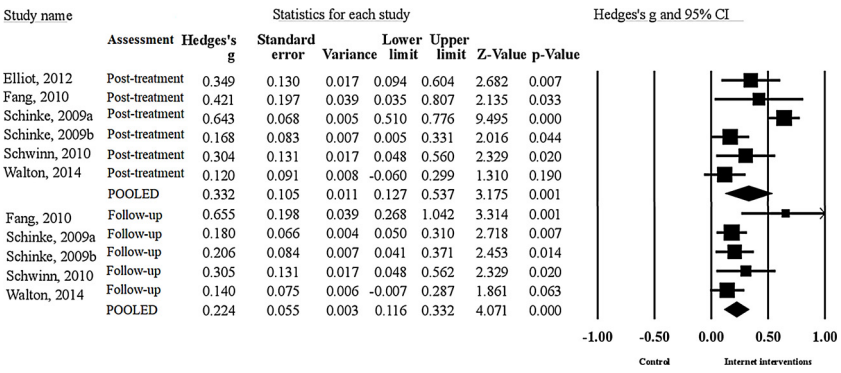

Fig. 2. Forest plot for cannabis use reduction in prevention interventions at post-treatment and follow-up (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).

Table 4
Subgroup analyses of associations between effect sizes and study characteristics (Hedges's g)[a].

		N comp	*g*	95% CI	I^2	95% CI	p[b]
Prevention studies ($N = 6$)		6	0.33	0.13–0.54*	83	65–92	
Subgroup analyses ($N = 6$)							
Intervention	Parent-involvement programs	3	0.41	0.06–0.77*	90	73–76	0.36
	Other[c]	3	0.23	0.08–0.38**	23	0–92	
Sessions in intervention	Single-session	2	0.22	−0.01–0.44	52	NA	0.34
	Multi-session	4	0.39	0.11–0.66**	86	64–94	
Analyses[d]	ITT analyses	3	0.38	0.03–0.43	91	76–96	0.77
	Complete-case analyses	2	0.23	0.02–0.45	28	NA	
Treatment studies ($N = 15$)		17	0.12	0.02–0.22*	45	3–69	
With one possible outlier removed (Towe and Stephens, 2014)		16	0.10	0.01–0.18*	31	0–62	
Subgroup analyses ($N = 15$)							
Guidance	Unguided	13	0.11	−0.01–0.22	44	0–71	0.81
	Guided	4	0.14	−0.11–0.39	54	0–85	
Intervention	MI	7	0.04	−0.12–0.20	28	0–69	0.32
	PNF	5	0.01	−0.11–0.30	59	0–85	
	MI + CBT	4	0.25	0.03–0.47*	35	0–77	
	Solution-focused therapy	1	0.20	0.08–0.31**	0	NA	
Sessions in intervention	Single-session	12	0.06	−0.06–0.18	40	0–69	0.07
	Multi-session	5	0.22	0.10–0.35**	18	0–83	
Recruitment	Clinical	5	0.20	−0.05–0.44	50	0–82	0.88
	Community	5	0.13	−0.03–0.29	21	0–67	
	University	5	0.09	−0.12–0.30	60	0–85	
	Website	2	0	−0.48–0.48	75	NA	
Analyses[d]	ITT analyses	13	0.11	0.01–0.21*	39	0–68	0.59
	Complete-case analyses	3	0.23	−0.25–0.70	75	19–93	

BI, brief intervention; CBT, cognitive-behavioral therapy; CI, confidence interval (* $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$); ITT, intention-to-treat; MI, motivational interviewing; NA, not available; N comp, number of comparisons; PNF, personalized normative feedback

[a] According to a random-effects model.

[b] The p-values in this column indicate whether the difference between the effect sizes in the particular subgroup is significant.

[c] 'Other' types of interventions are PNF, a skills-based prevention program, and BI.

[d] In this analysis we omitted one study because the authors did not mention whether they conducted ITT or complete-case analyses.

3.7. The post-treatment and follow-up effects of treatment interventions on Cannabis use

The treatment interventions that were compared to active comparison conditions (5 studies, $n = 1996$) – and which were therefore not included in the second meta-analysis (see Table 2) – reported varied effects. The study by Blow et al. (2017) found that a computer-delivered BI was as effective as a therapist-delivered BI, and that both interventions were significantly more effective than enhanced usual care. The study by Schwartz et al. (2014) found a computer-delivered BI to be more effective than a BI delivered by a behavioral health counselor. Budney et al. (2015) reported that a computer-delivered MI + CBT intervention was equally effective to a therapist-delivered MI + CBT intervention, and that both interventions were significantly more effective than a therapist-delivered BI; interestingly, the computer-delivered intervention was significantly more cost-effective than the therapist-delivered intervention. The study by Campbell et al. (2014) suggested that counseling combined with internet-delivered CRA seems promising for reducing Cannabis use outcomes as compared with counseling-only delivery, although the effects did not reach statistical significance. Finally, the study by Kay-Lambkin et al. (2011) reported that Cannabis use outcomes were not significantly different among computer-delivered MI + CBT, therapist-delivered MI + CBT, and person-centered therapy (PCT).

Assessing the studies included in the meta-analysis (15 studies, $N = 3813$), we found a small significant effect ($g = 0.12$; 95% CI 0.02 to 0.22) in terms of Cannabis use reduction at post-treatment for studies comparing treatment interventions with non-active control conditions. Heterogeneity was moderate (see Fig. 3 and Table 4). A visual assessment of the forest plot indicated one possible outlier (Towe and Stephens, 2014), in which the effect size did not overlap with the 95% CI of the pooled effect size (Fig. 3). For this reason, we removed the possible outlier, resulting in a minor decrease in the effect size. No publication bias was indicated via the assessment of the funnel plot and Duval and Tweedie's trim-and-fill procedure. Egger's test did not indicate an asymmetric funnel plot ($p = 0.89$). At the follow-up assessments of up to 12 months (9 studies), effects did not reach significance ($p = 0.10$). The subgroup analyses we conducted did not indicate a statistically significant difference between the groups (Table 4). The univariable meta-regression analyses did not reveal statistically significant associations between the effect sizes of digital interventions and (a) intervention duration in days (slope 0.005; 95% CI − 0.0006 to 0.01, $p = 0.08$), (b) number of sessions in the intervention (slope 0.03; 95% CI −0.01 to 0.06, $p = 0.158$), or (c) the risk of bias of the studies (slope 0.0007; 95% CI −0.07 to 0.07, $p = 0.984$). For the sake of rigor, we additionally report in Appendix F the effect on Cannabis use of the non-included treatment interventions that were compared with active control conditions. In Appendix G, we report the effect for studies that employed only toxicology screening results as outcome measures.

4. Discussion

We found that digital prevention and treatment interventions are effective in reducing Cannabis use at post-treatment, with prevention interventions producing a larger pooled effect size for Cannabis use reduction than treatment interventions. This finding is consistent with the face-to-face Cannabis intervention literature (Bender et al., 2011; Davis et al., 2015; Porath-Waller et al., 2010). Follow-up assessments indicated that the post-treatment effects were sustained for up to 12 months for the prevention interventions but not for the treatment interventions. This indicates that digital prevention interventions are a suitable approach to achieve a lasting small reduction in Cannabis use in comparison with non-active control conditions.

The subgroup analyses of the prevention and treatment interventions did not indicate a statistically significant difference between groups. However, among the treatment interventions we observed that multi-session interventions, such as those combining CBT with MI, produced higher effect sizes (6 comparisons, $g = 0.18$) than one-

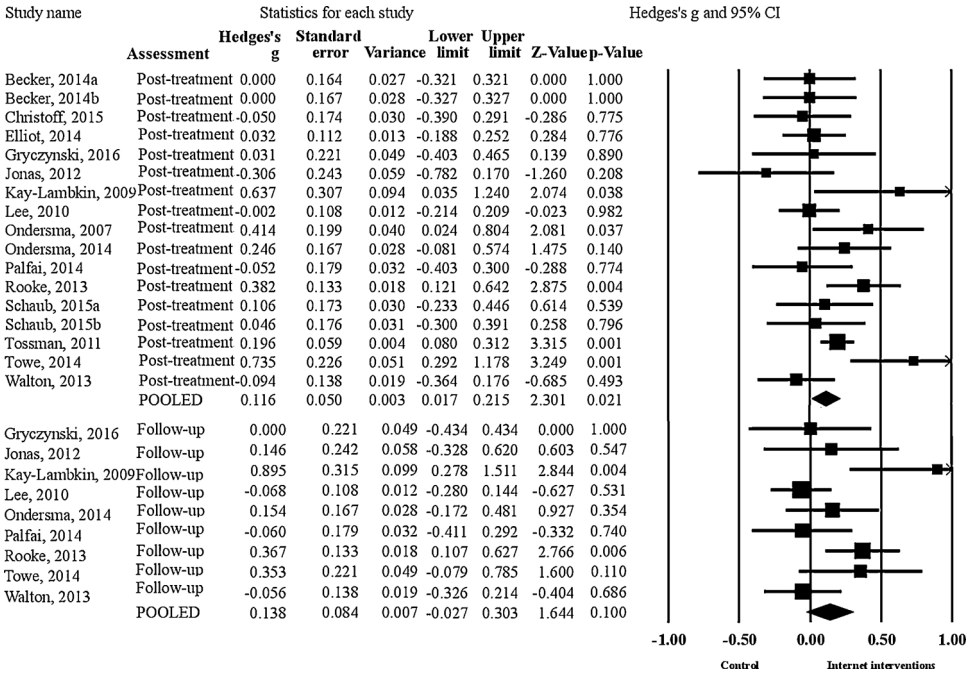

Fig. 3. Forest plot for cannabis use reduction in treatment interventions at post-treatment and follow-up (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).

session interventions using approaches such as PNF, MI, and BI (13 comparisons, $g = 0.09$); this has also been observed for digital interventions to reduce alcohol consumption (Riper et al., 2018). Our results should be interpreted with caution, however, as subgroup analyses in conventional meta-analyses have limited power for moderator analyses (Kraemer et al., 2002); individual patient data meta-analyses have the potential to overcome this obstacle (Karyotaki et al., 2017).

The outcomes of our meta-analyses are subject to certain limitations. Many studies, when assessed with the Cochrane risk-of-bias tool, satisfied only a small number of criteria. Our findings hence derive largely from low-quality RCTs. Given the nature of digitally delivered behavioral interventions, most included studies were at high risk of performance and detection bias. Only two RCTs were able to fully blind participants and personnel by fully automating the randomization procedure, thus ensuring that participants were unaware of the other conditions and that the outcome measure was unaffected by possible knowledge of the received intervention (Becker et al., 2014; Jonas et al., 2012).

As a result of limited public availability of RCT protocols or preregistrations, it was not possible for us to evaluate possible protocol violations, which have been shown to affect the validity of results (Sweetman and Doig, 2011). However, we observed that recently conducted RCTs tend to be of higher quality according to the Cochrane risk-of-bias tool and to be more often pre-registered with published protocols than earlier RCTs, leading to more transparency in a-priori defined research questions and in applied methods. A final limitation is that the applied intervention outcomes varied as to the time frames measured (with self-reported frequencies ranging from Cannabis use in the past week to the past six months) and the self-report questionnaires employed. The variation in outcome measures reflects the lack of an established gold standard for reporting Cannabis use frequency or quantity, such as the standard drink units used in the alcohol use literature (Greenfield and Kerr, 2008). The fact that Cannabis potency in terms of THC differs widely makes it difficult to reliably measure use without sophisticated toxicology screenings. However, toxicology screenings have their own disadvantages, such as the inability to detect mild Cannabis use or to reliably determine frequency of use by individuals, as well as the intrusions on the privacy of users who might prefer to avoid face-to-face contact with professionals.

Such obstacles highlight the importance of establishing a core outcome set for reporting Cannabis use outcomes. A recent example of such an ongoing project from the alcohol literature is the ORBITAL project (Shorter et al., 2017), which aims to develop an essential outcome measure set and guidelines for the reporting of efficacy and effectiveness trials involving brief interventions. A similar approach in the Cannabis use literature is needed to improve consistency across RCTs, minimize avoidable research waste, and improve inclusion rates in future systematic reviews that communicate noteworthy outcomes to stakeholders.

Regarding the observed lack of long-term effects in treatment interventions, we would like to point out that this shortcoming has also been observed in Cannabis treatment interventions delivered face to face (Gates et al., 2016). One of the interventions included in our systematic review attempted to increase and prolong the treatment effect via two booster sessions based on MI after the end of the initial intervention (Blow et al., 2017). No significant effect of the booster sessions was detected. Similarly, previous face-to-face treatment interventions failed to show a significant effect of booster sessions in drug users (Bogenschutz et al., 2014; Saitz et al., 2014). However, those findings contrast with conclusions that can be drawn from the alcohol literature, where booster sessions have previously been shown to increase or maintain treatment effects (Barnett et al., 2004; Braitman and Henson, 2016; Gwaltney et al., 2011; Wurdak et al., 2016). Similarly, a meta-analysis on mood and anxiety disorders has previously indicated that CBT-based booster sessions effectively augment treatment effect (Gearing et al., 2013). We therefore believe it would be worthwhile to further investigate the effects of booster sessions in varied target groups.

If we compare effect sizes resulting from digital Cannabis use interventions, as reported in the literature, with those of face-to-face interventions, we can observe that digital prevention and treatment interventions still produce smaller effect sizes than face-to-face prevention ($d = 0.58$) and treatment interventions ($g = 0.49$) (Davis et al., 2015; Porath-Waller et al., 2010). In contrast, a recent meta-analysis from the depression literature has indicated that digital intervention may be equally effective to face-to-face interventions

(Carlbring et al., 2018). We are confident about the feasibility of further enhancing the effectiveness of digital interventions for Cannabis use reduction. We therefore suggest that future studies should investigate novel approaches for increasing the effect sizes of digital interventions. One possible approach might be to develop and assess blended interventions that combine digital and face-to-face elements of therapy. A recent meta-analysis concluded that blended interventions might decrease attrition among patients, increase abstinence rates of substance users, assist in maintaining treatment effects in the long term, and reduce clinician time. That could translate into a cost-effective alternative to traditional treatments (Erbe et al., 2017).

5. Conclusions

Digital prevention and treatment interventions produce small, significant Cannabis use reduction effects at post-treatment as compared to non-active controls. Prevention interventions produce higher effect sizes that are later maintained at follow-up, while the follow-up effects of treatment interventions seem to be clinically negligible. Given that prevention interventions target a range of participants that include non-users, it would be worthwhile to explore additional outcome measures, such as delay of Cannabis use onset, in addition to reduction of use, since delaying the onset of Cannabis use in adolescents could significantly improve health outcomes that will last throughout adulthood (Lisdahl et al., 2013).

Given the large number of Cannabis users and the physical and mental health consequences associated with problematic Cannabis use, we suggest that digital interventions have the potential to decrease Cannabis use in a variety of target users and different settings. They may have a small effect, but when implemented on a large scale at low cost they could produce substantial health gains. More research is needed, however, in the form of large, well-designed RCTs, in order to arrive at firmer conclusions about the effects of digital interventions on Cannabis use and to enable the investigation of moderators that possibly affect Cannabis use.

Future studies should, whenever possible, attempt to blind participants and personnel by fully automating the randomization procedure, in order to ensure that participants are unaware of other conditions and prevent performance bias. This practice would also prevent detection bias by ensuring that outcome measures are unaffected by possible knowledge of the received intervention. Furthermore, future studies should investigate the effects of booster sessions in varying target groups, as these might be capable of increasing or maintaining treatment effects. Blended interventions combining digital and face-to-face elements should also be assessed for Cannabis use reduction; these types of interventions have previously shown promising results.

Contributors

N. Boumparis, M. Blankers, D. Ebert, D. Korf, M. Schaub, R. Spijkerman, R. Tait, and H. Riper designed the study. N. Boumparis and L. Loheide-Niesmann managed the literature searches and the data extraction. N. Boumparis, L. Loheide-Niesmann, and H. Riper checked the consistency of data extraction. N. Boumparis, L. Loheide-Niesman, and H. Riper wrote the manuscript. The drafts of the paper were revised by all authors. All authors contributed to and have approved the final manuscript.

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Conflict of interest

No conflict declared.

Permission note

The attached manuscript contains only original content.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/J.drugalcdep.2019.03.016.

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